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Seasonal and diel patterns in cetacean use and foraging at a potential marine renewable energy site

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ABSTRACT

Marine renewable energy (MRE) developments often coincide with sites frequented by small cetaceans. To understand habitat use and assess potential impact from development, echolocation clicks were recorded with acoustic click loggers (C-PODs) in Swansea Bay, Wales (UK). General Additive Models (GAMs) were applied to assess the effects of covariates including month, hour, tidal range and temperature. Analysis of inter-click intervals allowed the identification of potential foraging events as well as patterns of presence and absence. Data revealed year-round presence of porpoise, with distinct seasonal and diel patterns. Occasional acoustic encounters of dolphins were also recorded. This study provides further evidence of the need for assessing temporal trends in cetacean presence and habitat use in areas considered for development. These findings could assist MRE companies to monitor and mitigate against disturbance from construction, operation and decommissioning activities by avoiding times when porpoise presence and foraging activity is highest in the area.

1. Introduction

Marine renewable energy (MRE) has the potential to reduce fossil fuel dependency in coastal nations with appropriate tidal and wave energy resources (Manasseh et al., 2017). To utilise these resources in South West Wales (UK), a tidal lagoon development has been proposed for the inner Swansea Bay that encompasses an area of 11.5 km^2 with a 9.5 km^2 breakwater designed to harness electricity from the natural ebb and flow of the ocean tide, using submerged hydro turbines. Swansea Bay has a large natural tidal range, the second highest in the world, with a difference of up to 10.5 m making it an ideal site for MRE development. The Swansea Bay Tidal Lagoon will be a unique construction and the world's first tidal lagoon power plant with an estimated > 530 GWh net power output capacity capable of powering 155,000 homes annually. Recent increases in MRE construction and operation, particularly of windfarms but also of wave and tidal devices, pose a potential threat to many cetacean populations (Brandt et al., 2011; Carstensen et al., 2006; Dähne et al., 2013). These include disturbance from construction and operation noise and increased boat traffic in the area; risks of collision and entanglement; potential loss of habitat and adverse effect on prey species (Dolman and Simmonds, 2010; Simmonds and Brown, 2010; Wilson et al., 2007).

The most common cetacean species in European waters, and thus the most likely species to be affected by MRE development is the harbour porpoise (*Phocoena phocoena*) (Baines and Evans, 2012; Reid et al., 2003). Although protected by the EU Habitats and Species Directive, which requires the monitoring of its conservation status, little is known about the habitat use or residency patterns of this evasive cetacean species (Embling et al., 2010). Without distinct markings, it is difficult to identify individuals and ascertain home ranges for such a mobile species (Embling et al., 2010). Satellite tagging studies from Denmark show remarkably long distance travel paths for the Baltic harbour porpoise (Sveegaard et al., 2012) and there is no evidence to suggest that the same would not be true for porpoise in UK waters. Previous studies have found evidence of seasonal and diurnal patterns in the occurrence of harbour porpoise with greater detections at night albeit with distinct spatial variations often attributed to prey availability (Carlstrom, 2005; Schaffeld et al., 2016; Todd et al., 2009). Harbour porpoise are known to be opportunistic feeders and foragers and many studies have highlighted the importance of sediment substrate and water depths on their distribution and behaviour and feeding patterns (Brandt et al., 2014; Brookes et al., 2013; Mikkelsen et al., 2013; Todd et al., 2009; Williamson et al., 2016). For example, Williamson et al. (2017) studied diurnal variation in harbour porpoise detection based on sediment type and water depth in Moray Firth, Scotland, and found increased foraging behaviour in muddier, deeper habitats at night but increased diurnal patterns in shallower sandy habitats overall. In addition, the tidal flow is also an important determinant of porpoise distribution in high energy environments, where acoustic encounters of porpoises have been shown to vary significantly at very small

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spatiotemporal scales (Benjamins et al., 2017). A better understanding of the fine scale seasonal and diurnal patterns in distribution will provide more insight into habitat use by these small cetaceans, and provide the evidence needed to protect them against potential anthropogenic impacts.

Previous visual and acoustic studies have shown year-round presence of porpoises in Swansea Bay with possible summer peak in frequency of observations (Baines and Evans, 2012; Watkins and Colley, 2004), although typically the area is thought to be less frequented by the species in comparison to 'hotspots' in Welsh waters, such as West Pembrokeshire and Cardigan Bay (Baines and Evans, 2012). The harbour porpoise population in Swansea Bay is generally considered to be part of the Celtic Sea management unit which spans across the Irish Sea, Celtic Sea, Western English Channel and Southwest Ireland (Evans, 2012). Recently a candidate Special Area of Conservation (SAC) was proposed for the Bristol Channel Approaches for harbour porpoise during winter season but this did not include Swansea Bay within its boundaries (JNCC, 2016).

1.1. Rationale for acoustic monitoring

Visual surveys, whether land, aerial or boat-based are particularly limited by daylight, weather conditions and visibility (Evans and Hammond, 2004). Static acoustic monitoring (SAM) is a widely used to complement visual methods and are typically used to describe fine-scale temporal patterns in habitat use for vocalising cetaceans (Brookes et al., 2013; Thompson et al., 2015; Williamson et al., 2017). Data recorders, such as C-PODs, enable continuous monitoring throughout the diel cycle, in all seasons and in adverse weather conditions (Simon et al., 2010), although high levels of noise in the recording frequency band (such as heavy rain, or dolphin echolocation right next to a data logger) may cause the recorder's memory to fill up (Tregenza, 2014). Static devices can be used to understand fine scale temporal patterns otherwise missed by visual surveys, although they can have limited spatial coverage (Brookes et al., 2013), unless resources allow for the deployment of numerous devices.

Echolocation click signals can be recorded using bottom moored, automated underwater click loggers called C-PODs (Chelonia Ltd., Cornwall, UK, www.chelonia.co.uk), which autonomously log times and characteristics of echolocation clicks. The loggers detect echolocation clicks between 20 and 160 kHz, and can be used to study presence, relative abundance, foraging behaviour, habitat use and distribution of cetacean species (Benke et al., 2014; Berrow et al., 2009; Carlstrom, 2005; Nuuttila et al., 2013a, 2013b; Pirotta et al., 2014; Rayment and Dawson, 2009; Schaffeld et al., 2016; Simon et al., 2010; Verfuß et al., 2007) and have been widely used to assess anthropogenic disturbance from wind farms, shipping, fisheries and coastal development (Carlstrom, 2005; Carstensen et al., 2006; Cox et al., 2001; Todd et al., 2009).

Clicks are logged if they show a sufficiently high peak sound pressure level and a distinct spectral peak in the frequency range covered. Specific software classifies detected sounds into sequences called click trains. These are further categorised based on their likely origin (boat sonar, dolphin, or porpoise click trains) according to known characteristics. Harbour porpoises and most delphinids produce high frequency clicks for navigation as well as prey detection and discrimination and prey capture. Echoes provide information on the range of their prey targets and allow the animals to detect objects outside their visual range (Au and Fay, 2000). Porpoises echolocation signal is highly stereotypical, containing very short clicks (50–150 μs) and very little energy below 100 kHz (Au et al., 1999; Teilmann et al., 2002; Villadsgaard et al., 2007). The main part of the energy is within a narrow band of 120–150 kHz, making them ideal for automatic acoustic detection, since most other noise in the sea usually contains energy over a wider frequency range, is of much longer duration, and has peak energy at much lower frequencies. Furthermore, porpoise echolocation clicks have decreasing or increasing temporal pattern whereas most other noise in this frequency band (*i.e.* boat echo sounders) produce very regular clicks (Teilmann and Carstensen, 2012). Delphinid clicks can also be detected by C-PODs, and they can be distinguished from porpoise clicks as they are shorter, more varied, with much higher source levels and have energy across a wider frequency band (Au et al., 1974; Au and Hastings, 2008; Wahlberg et al., 2011). Dolphins, do not, however, always echolocate and therefore have a lower probability of being detected as compared to porpoises (Nuuttila et al., 2013a; Philpott et al., 2017), who echolocate almost continuously (Akamatsu et al., 2007; Linnenschmidt et al., 2013). Presence of dolphins can affect porpoise acoustic behaviour and interfere with performance of the acoustic dataloggers. It was therefore necessary to ascertain dolphin presence in the study area. From opportunistic land based observations and from local boat trip operators we also know that occasional sightings of common dolphins (*Delphinus delphis*) and bottlenose dolphins (*Tursiops truncatus*) have been made in the area (Robinson, Sea Watch Foundation, pers. comm.). Recent photographic evidence confirms a group of Risso's dolphins (*Grampus griseus*) spotted off Mumbles headland, west side of Swansea Bay (Hunt, pers. comm.).

The aim of this study was to use static acoustic dataloggers to explore temporal patterns in cetacean habitat use and foraging in and around the proposed Swansea Bay Tidal Lagoon development site. This information is crucial for assessing potential risks to cetaceans from the tidal lagoon as well as mitigating against them to ensure successful development of MRE infrastructure in Wales. Perceived threats to cetaceans from most MRE devices and structures are linked to collision risk, entanglement and displacement due to habitat loss and/or prey depletion (Dolman and Simmonds, 2010; Simmonds and Brown, 2010). Here we show the importance of understanding localised patterns in habitat use to assess potential impacts of MRE developments on cetaceans in coastal waters.

2. Materials and methods

2.1. Study area

Swansea Bay (Wales, UK) is a large sweeping sandy bay located on the northern coastline of the Bristol Channel with a depth of < 20 m OD (Fig. 1) (Pye and Blott, 2014). The bay is a shallow embayment with an anticyclonic gyre and a rectilinear current offshore dominated by refracted waves from the southwest (Davies, 1974). The geology of the bay is largely characterised by relict Pleistocene bed sediments overlain by unconsolidated and poorly sorted glacial till, pebbles, sand and silt and a large area of the outer Swansea Bay is a historic dredge spoil ground from the local docks. At Mean Low Water (MLW) approximately 618 ha of intertidal mudflats and sand bars are exposed. Water quality is largely influenced by the hydrology of the three river catchments (Tawe, Neath and Afan) serving Swansea Bay in addition to historical and current diffuse pollution.

The Swansea Bay Tidal Lagoon site location (Fig. 1) is situated between the River Tawe and Neath connecting the Swansea Docks in the west to the Swansea University Bay Campus in the east. The development encompasses the main sewage outfall, southwards of Swansea Docks, of the Swansea catchment, an area which is known to be frequented by harbour porpoise.

2.2. Deployment sites

Acoustic data loggers were deployed in four locations in the Swansea Bay area (Fig. 1); inside the proposed lagoon site, by a sewage outfall pipe ('Outfall'), east of Mumbles, ('Mumbles'), outside the Swansea Bay, in Oxwich Bay ('Oxwich') and offshore, in Scarweather sandbank ('Scarweather'). The sites were selected away from main shipping lanes and dredging and fishing areas and to maximise likelihood of porpoise detections. The deployment site coordinates, average